

Irrigation Levels and Potassium Doses in the Growth of Sunflower Cultivated in soil of the Brazilian Cerrado

ABSTRACT

The chief limiting factor in sunflower (*Helianthus annuus* L.) development is water deficit. Besides the dearth of water, large amounts of mainly potassium (K) are essential for the favorable development and bountiful harvest of the culture. This study aimed to evaluate the growth of sunflower plants cv. SYN 042 cultivated in red Cerrado Oxisol with controlled irrigation levels and K doses. Randomized block design was selected in a 5x4 factorial scheme, administering 5 K doses (0, 40, 80, 160 and 240 mg dm⁻³ of K₂O) and 4 different water replacement levels in the soil (75, 100, 125 and 150% of field capacity (FC)), with 4 replications. The following characteristics were evaluated: Plant height, stem diameter, Chlorophyll index, , inner and outer diameters of the chapter, and dry mass of the stem. When 150% water replacement level of field capacity was utilized, it induced an increase in the plant growth as observed in terms of stem diameter, inner and outer diameters of the chapter, plant height and stem dry mass. The K added as fertilizer significantly affected the plant height, inner and outer diameters of the chapter, SPAD (direct index chlorophyll content), and stem dry mass, during the assessment performed at 60 days post emergence. The sunflower plants displayed improved development when the irrigation levels and K doses were estimated in isolation. The 150% water replacement level of field capacity provided the best results of development and growth of sunflower in Oxisol of the Cerrado.

Key words: Sunflower, Irrigation management, Oxisol, Potassium concentration

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) falls into the category of plant species that have the highest potential to produce renewable energy in Brazil. It is cultivated mainly for oil production for human consumption as well as for biofuel [1] and its by-product also finds use as an animal feed supplement.

From an agricultural perspective, sunflower cultivation is valued as a profitable alternative compared with other crops, because of its desirable features including its short cycle, production of good quality and quantity of oil, drought tolerance, high level of adaptability and lower production costs than any other oil [2]. Brazilian producers, thus, regard sunflower production as a viable option for additional income [3,4].

Drought is the prime limiting factor on plant growth [5]. It has become common for most farmers to regard irrigation supplemented with mineral fertilizers as advantageous to crops. K is the second most absorbed element by plants, and according to [6] is an abundant cation, most often in its water-soluble form, observed in the tissues. It is considered one of the more mobile among the nutrients in the soil-water-plant system and especially so within the plant [6].

The low and insufficient concentration of K reserves found in a large part of the Cerrado soils have contributed towards limiting the productivity of the cultivations [7]. To boost this naturally occurring low concentration of nutrient, supplementation with fertilizers becomes necessary for the plants to flourish [8].

Beginning with the hypothesis that the combined effect of irrigation levels and K doses affects the plant growth, development and nutrition of the sunflower crop, this study aimed at assessing the growth patterns of sunflower plants cv. SYN 042 cultivated with different of water replacement levels in the soil and K doses in the Cerrado Oxisol.

2. MATERIALS AND METHODS

The experiment was performed in a greenhouse from April to August of 2015 at the Federal University of Mato Grosso, Campus of Rondonópolis - MT. The used greenhouse in the experiment had a metal frame, covered with polyethylene film and an adiabatic cooling system. It was in the north-south direction, extending across a total area of 450 m². The geographic location was latitude 16°27'49 " South, longitude 54°34'47 " West at an altitude of 284 m.

For the experiment, a sandy loam Oxisol [6], was collected from a depth of 0.0 - 0.2 m layer, used to fill the experimental plots, after passing it through a 4 mm mesh size sieve. One soil sample was sieved through a 2 mm mesh to study chemical properties and particle-size composition.

After analyses the soil, following chemical and textural characteristics were recorded: pH (CaCl₂ 0,01M) = 4.1; P (Mehlich-1) = 2.4 mg dm⁻³; K (Mehlich-1) = 28 mg dm⁻³; Ca (Extraction KCl 1M) = 0.3 cmolc dm⁻³; Mg (Extraction KCl 1M) = 0.2 cmolc dm⁻³; Al (Extraction KCl 1M) = 1.1 cmolc dm⁻³; atomic Absorption Readings were performed for Ca and Mg and acid titration for Al; H = 4.2 cmolc dm⁻³; Organic Matter (OM) = 22.7 g dm⁻³ by titration - Walkley Black; Sand = 549 g kg⁻¹; silt = 84 g kg⁻¹; and clay = 367 g kg⁻¹; sum total of the bases cmolc 0.6 dm⁻³; Cation Exchange Capacity (CEC) = 65.9 cmolc dm⁻³; Base Saturation (V) = 9.8%.

The randomized block design was selected for the experiment in which a total of 80 experimental plots represented by 20 dm³ capacity plastic pots were arranged in a 5x4 factorial scheme. It involved 20 treatments and 4 replications. The treatments consisted of 5 K doses (0, 40, 80, 160 and 240 mg dm⁻³ of K₂O) and 4 irrigation water replacement levels in the soil (75, 100, 125 and 150% of field capacity (FC)). The experimental units were organized into 4 blocks each having 20 treatments units.

Sunflower (*Helianthus annuus* L.) cultivar SYN 042 was the plant species used, having a short cycle, equal to 90-100 days of cultivation after sowing. The sunflower sowing was accompanied simultaneously by the addition of fertilizer. All the treatments were fertilized with N, P₂O₅ and micronutrients, the sources were urea, superphosphate and formulated FTE BR-12, respectively.

The recommended P dosage was 150 mg dm⁻³ of P₂O₅ single superphosphate (0-20-0) applied in solid, granular form. N fertilization was performed into 2 installments, applying 20 mg dm⁻³ at sowing time and 80 mg dm⁻³ coverage at 30 days after sowing (DAS), both in solution form. A top dressing of 40 mg dm⁻³ of formulated FTE BR-12 (Sulfur: 3.9%, Boron: 1.8%, Manganese: 2.0% and Zinc: 9.0%) was also applied. Potassium chloride (KCl) was the potassium source added to the soil at planting, corresponding to the treatment doses (0, 40, 80, 160 and 240 mg dm⁻³ K₂O).

The irrigation management used was based on the tensiometer. Therefore, to correlate the soil moisture assessed by water consumption of the crop throughout the cycle with the matrix potential, the soil water retention curve in equation 1 was determined.

The Soil Water Retention Curve - SWRC computer program [9] was employed to mathematically adjust the results to the non-linear model proposed by [10], who explained the action of moisture as a function of the water tension from the soil.

$$\Theta = \frac{0.46}{[1 + (0.053 |\Psi_m|)^{0.3545}]^{0.5724}}$$

(1)

In which:

θ - Volumetric soil water content in cm³ cm⁻³;

ψ_m - water potential in the soil, in cm;

80 To estimate the water tension levels in the soil puncture tensiometers were installed in the vessels,
81 one per block, totaling to 4 tensiometers. Irrigation management was then performed from the
82 average reading of the tensions observed in the 4 tensiometers installed in the experimental units with
83 100% water replacement in the soil and a reference dose of 80 mg dm⁻³ of K.

84 The water tension in the soil was monitored with a digital tensiometer having a precision of 0.1 kPa.
85 Irrigation time indicated the average stress attained by the four tensiometers to reach the next value
86 of 10 kPa.

87 Manual irrigation was performed using a graduated and calibrated cylinder to raise the tension values
88 to the field capacity of 6 kPa for all the treatments at the 100% water replacement level in the soil
89 when the established tension of 10 kPa was achieved. [11] reported that field capacity values up to 5
90 kPa in typical Cerrado soil were a common occurrence.

91 Using the tensions observed the corresponding humidity values were calculated from the water
92 retention curves in the soil. Thus, the volume of water replacement in the soil was calculated with
93 these humidities and the values corresponding to the field capacity, by the equation given below.

94
95
$$V = (\theta_{FC} - \theta_{actual}) * 20000 \quad (2)$$

96 In which:

97 V - Water volume in cm³;

98 θ_{FC} - moisture at field capacity in cm³ cm⁻³;

99 θ_{actual} - moisture retention curve according to the tension observed in cm³ cm⁻³;

100 20,000 - Volume of soil inside the pot, in cm³;

101

102 Water replacement levels utilized in each experimental unit were set according to the percentages for
103 each treatment.

104 Growth and development of sunflower plants were assessed and analyzed at 60 days after plant
105 emergence, evaluating the following aspects:

106

107 Plant height was measured by measuring the distance between the plant collar (soil surface) and the
108 upper end of the main stem, with the help of a ruler.

109

110 Leaf number: the counting of the leaves present in each experimental plot was performed, in which
111 the ones with a minimum length of 4 cm were considered.

112

113 Stem diameter: was obtained from a reading average of the two plants contained in the pot, at a
114 height of 5 cm from the soil surface, with the aid of a digital caliper.

115

116 Direct index chlorophyll content reading: obtained from the average of five readings performed in
117 random sheets in the middle third of the plants, with the aid of the chlorophyll meter chlorophyll meter
118 Minolta SPAD-502.

119

120 Inner and outer diameters of the chapter: were measured using a tape measure.

121

122 Dry mass and stems: the stems were packed in paper bags, identified and transferred to a
123 greenhouse at 65 ° C for 72 hours, and then weighed.

124

125 The results were statistically analyzed using the statistical program SISVAR [12] with the analysis of
126 variance and regression tests performed for a significance level at 5% of probability.

127

3. RESULTS AND DISCUSSION

The analysis of variance revealed a significant effect for the interaction between irrigation levels and potassium doses 60 days after plant emergence, only for the stem dry mass variable. However, there was a significant effect, in isolation, of factors irrigation levels and doses of potassium, for the other variables analyzed.

The height of sunflower plants was influenced by irrigation levels and K doses, in isolation (Figures 1A and 1B). It is observed that this variable, according to the levels of irrigation, adjusted to the linear regression model, with increasing water levels up to 150% of field capacity, providing the highest plant height (151.52 cm) at 60 days after emergence (Figure 1A).

Plant heights at 60 days after emergence varied significantly with the K doses showing a fit to the linear regression model, and the increment in response to the K_2O dose of 240 $mg\ dm^{-3}$ produced a height of plants of 141.57 cm (Figure 1B).

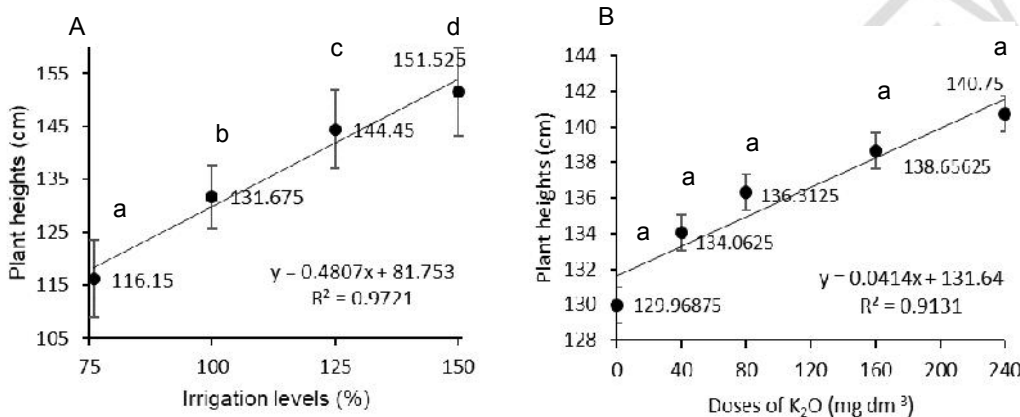


Figure 1. Plants height submitted to irrigation levels (A) and K_2O doses (B) in red Cerrado Oxisol. Averages followed by the same letter do not differ statistically from each other by with post hoc test from tukey at 5% probability.

*** significant regression test at the 0.1% probability level. No significant differences in 1B, please omit regression curve

One explanation for the influence of water levels on the vegetative growth of the sunflower plant is that the water stimulates a higher amount of carbohydrate assimilation, a significant factor which stimulates photosynthesis and increases the leaf surface. [13] proposed that the leaf expansion rate and photosynthetic contribution are linked to the vegetative growth rate and increased leaf area which involves a heightened production of assimilates essential for good quality production.

Variations in the availability of water in the soil, probably caused the reduction in the water potential in the stem cells of the sunflower plants, producing a smaller cell elongation and internodes, culminating in smaller growth in these plants [14].

The increase in plant height observed in response to the increasing K uptake occurred because K can stimulate the enzymatic activation in the N transportation process resulting in cell growth and development, producing more tissues in the plant [15]. However, when K was not used as a fertilizer, and there was an insufficiency of nutrient levels in the soil, the plant registered a lower growth rate.

[16] in an experiment on sunflower response submitted to doses of boron and potassium verified that the maximum height of the sunflower was obtained with the application of potassium of 90 $kg\ ha^{-1}$ of K_2O and comparing with the height of the plants where they were not supplied with this nutrient, the authors observed that the sunflower presented a reduction of 33% of the maximum height obtained, confirming the importance of supplying this nutrient to the sunflower crop.

The water replacement levels in the soil revealed an isolated significant effect in setting the linear regression model for stem diameter; the greatest diameter found was 11.28 mm showing a 20% increase with the highest water replacement level in the soil (150% FC) when compared with the level that induced the least diameter (75% FC) (Figure 2A).

With respect to the chlorophyll index, a significant effect of the K concentration in the soil was noted only above 160 mg dm⁻³ with respect to control. The K fertilizer positively influenced the chlorophyll concentration in the sunflower leaves adjusting the quadratic regression model, and thus reiterating that the quantity of K₂O 133.5 mg dm⁻³ was responsible for the higher chlorophyll content (42.12) (Figure 2B).

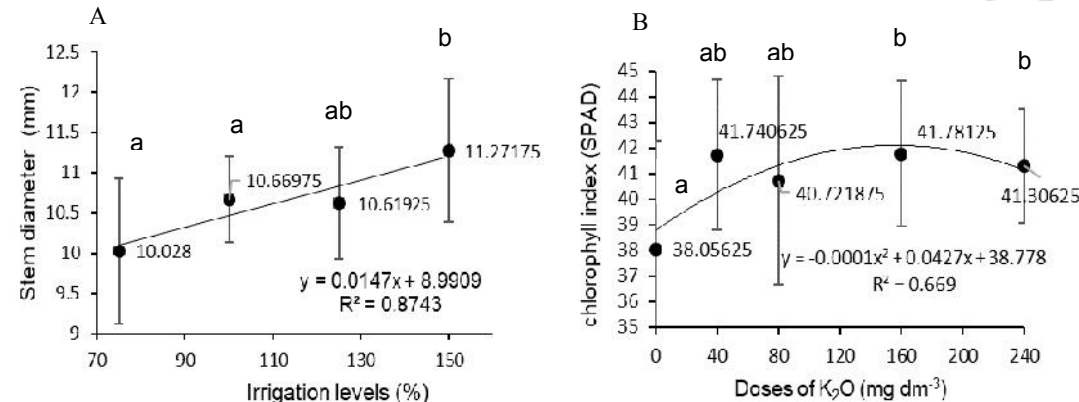


Figure 2. Diameter of the stem as a function of irrigation levels (A) and chlorophyll index in response to K₂O (B) doses in Red Cerrado Oxisol. Averages followed by the same letter do not differ statistically from each other by with post hoc test from tukey at 5% probability. *, * significant regression test at the 0.1 and 5% respectively probability level. Please check the regression curve**

The results from this study corroborates with [17] who noted that the decrease in the water storage in the soil resulted in the development of a smaller stem diameter.

The stem diameter increase can be correlated to the production of ethylene; this is because in the presence of excess water, larger amounts of this hormone are produced, resulting in lesser root growth. This in turn causes an increase in the lateral roots and underarm and is visible as greater stem diameter. Stem diameter is significant in sunflower, because it decreases the layering of the culture, enhancing their management, cultivation and harvesting [18].

The rise in the chlorophyll content is because the chloroplasts possess about one-half of the K nutrients of the leaf. This stimulates greater diffusivity of the CO₂ in the mesophyll cells, thus raising the degree of photosynthetic activity [19].

It is also now possible to understand that the addition of the K fertilizer positively influences the SPAD index, if administered accurately. It also increases the N uptake and transport, the stomatal movement occurs by the entrance and exit of potassium ions (K⁺) from the guard cells, regulating the entry of CO₂ that serves as fuel for photosynthesis according to [20]. K deficiency induces irregular stomatal functions, which may decrease the CO₂ assimilation and consequently the photosynthetic rate [21], thus negatively affecting the production.

At 60 days post emergence a linear increase was observed in the internal and external diameters of the sunflower chapter as the water replacement levels increased. For the highest water replacement level in the soil, a diameter of 10.47 cm and 23.29 cm, respectively, was recorded, showing a 28% increase when the highest water replacement level in the ground (150% of FC) was compared with the least degree of irrigation applied (75% of FC) (Figs. 3A and 3B).

The application of K fertilizer was found to influence the inner diameter of chapter **lower diameter for absence of K₂O -> from 40-240mg dm³ no significant difference are reported**, setting the quadratic regression model with the higher value (10.33 cm) induced by the K dose of 183.72 mg dm⁻³. The highest dose (240 mg dm⁻³) was observed to produce the greatest value of the outer diameter (22.53 cm) resulting in a 5% increase in the outer diameter of chapter when compared with the plants which were not treated with the potassium fertilizer (Figures 3C and 3D).

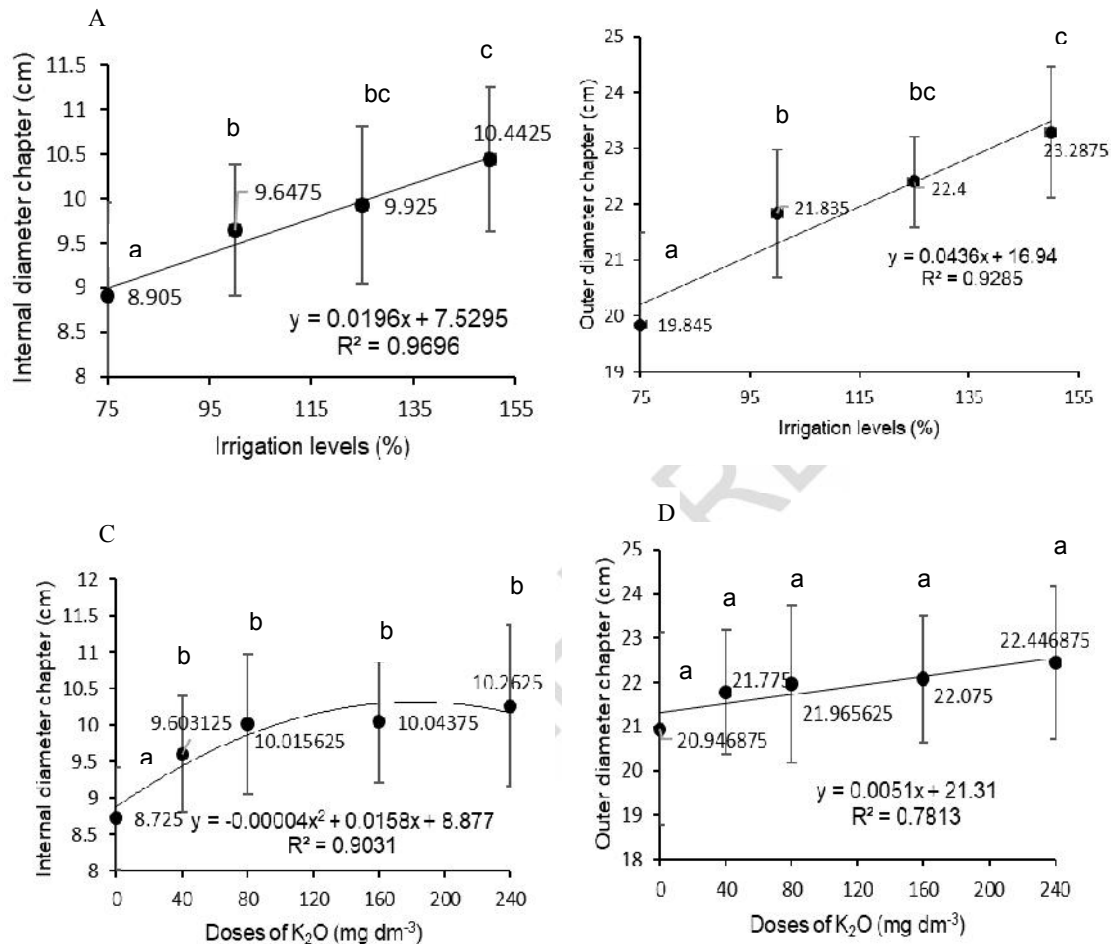


Figure 3. Internal and external diameter of the chapter of the sunflower based on the water replacement levels (A) and (B) and the K₂O doses (C) and (D) in Red Cerrado Oxisol. Averages followed by the same letter do not differ statistically from each other by with post hoc test from tukey at 5% probability.

***, ** significant regression test at the 0.1 and 1% probability level respectively. **No significant differences in 3D, please omit regression curve**

Similar results were reported by [22] with the larger diameter of 11.9 cm observed in response to doses above 60 kg ha⁻¹ K₂O.

In their study, [4] compared the growth and productivity of the sunflower plants under various irrigation levels, reporting a significant difference between the inner and outer diameters of the sunflower chapters, depending on the water replacement levels applied. They also suggested the possibility of achieving a higher grain production because of the larger sizes, on average, of the chapters. According to [23] water availability is an important factor that limits the sunflower crop, and its production is greatly affected by the irrigation levels.

The F test showed that the stem dry mass was significantly influenced at the 5% level of probability, the interaction between the irrigation levels and K doses. The regression analysis for the averages of the K fertilizer levels, considering the water replacement levels in the soil, revealed a quadratic response to the 100 and 150% levels. For the 75 and 125% levels the linear behavior for K dosages was observed.

At the 75 and 125% levels of field capacity a linear increase in stem dry mas was reported in response to the 240 mg dm⁻³ dose of K (Figure 4), corresponding to 25.66 and 37.67 g, respectively. For 100 and 150% irrigation levels of field capacity the K doses induced higher degrees of stem dry mass (30.09 and 47.29 g) which were 185.5 and 232.37 mg dm⁻³, respectively (Figure 4).

Regression analysis performed for the medium levels of water availability, considering the K levels, revealed a quadratic response to the 0 mg dm⁻³ dose. For the 40, 80, 160 and 240 mg dm⁻³ doses of K₂O the linear behavior was evident for the irrigation levels (Figure 5). For the 0 mg dm⁻³ dose of K₂O, the irrigation level induced a greater stem dry mass in the sunflower plants (26.19 g) which was 137.02% of FC.

For the 40, 80, 160 and 240 mg dm⁻³ doses of K₂O a linear increase in the stem dry mass was noted (32.02, 39.01, 43.93 and 46.58 g, respectively) in response to the increase in the water levels, an increase of 68.11, 87.57, 93.35 and 93.98%, respectively, compared with the highest water replacement level in the soil (150% of FC) with the lowest water replacement level applied (75% of FC).

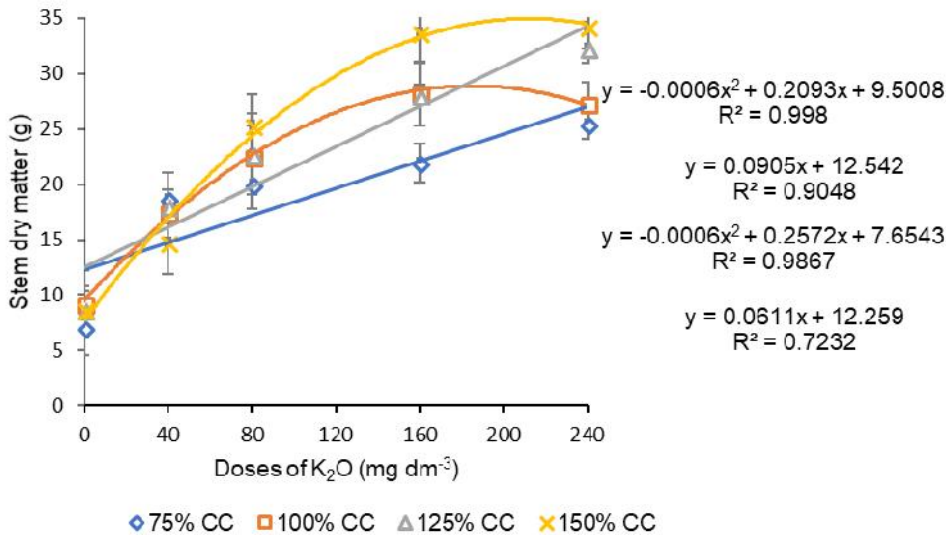


Figure 4. Dry mass of the stem due to combinations of K₂O doses and soil irrigation levels of 75, 100, 125 and 150% of CF in Red Cerrado Oxisol.
**** significant regression test at the 1% probability level.**

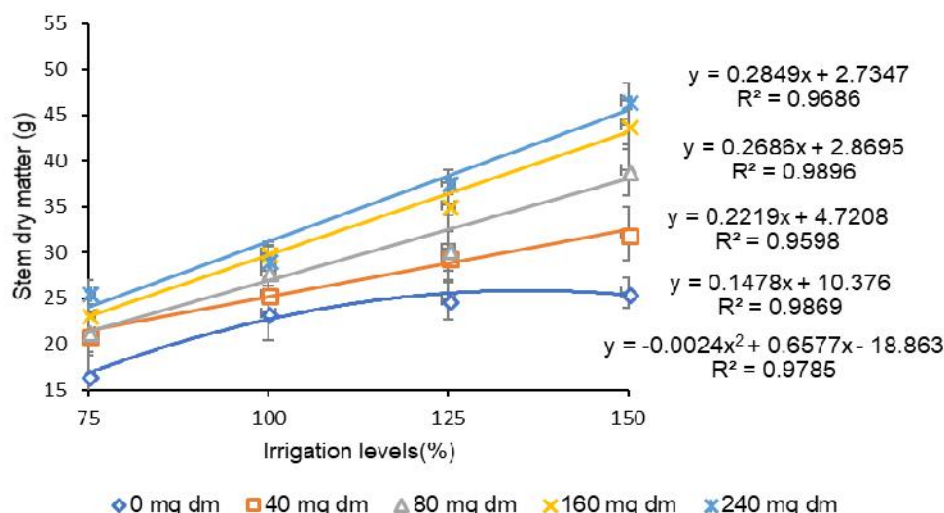


Figure 5. Dry mass of the stem due to combinations of irrigation levels and potassium doses of 0, 40, 80, 160 and 240 mg dm⁻³ in Red Cerrado Oxisol.

** significant regression test at the 5% probability level.*

[1], reported a linear growth in the shoot (leaves, stems and roots) dry mass of the sunflower with an increase in the water depth; the increase recorded was 280.88% compared with the treatment under hypoxic conditions and 40% water requirement.

Optimal and well distributed amounts of water supply during the plant cycle are crucial for growth. According to [24] any decrease in the total dry mass of the sunflower plants is the direct result of drought during the growth and development period of the plants, which would show reduced leaf area and thus slower photosynthetic process. This results in the low production of assimilates and poor development of the leaves, stem and chapters.

4. CONCLUSION

The more water available for the sunflower plants, the higher their output in terms of the quantitative growth parameters, plant height, stem diameter and inner and outer diameters of the chapter.

The most favorable range of doses of K as fertilizer required to maximize the growth and development of sunflower plants was 133.5 to 240 mg dm⁻³.

Decreases in the water available in the soil negatively influences the growth and biomass accumulation in sunflower plants SYN 042.

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